CLAIMS:

1. A method for forming a metal layer, comprising the steps of:

(a) forming a sacrificial metal atomic layer on a semiconductor substrate;

(b) removing the sacrificial metal atomic layer and concurrently forming a metal atomic layer on the semiconductor substrate by reacting the sacrificial metal atomic layer with a metal halide gas; and,

(c) stacking a plurality of metal atomic layers on the semiconductor substrate by alternately forming the sacrificial atomic layer and the metal atomic layer, at least once.

2. The method of claim 1, further comprising the step of forming an initial sacrificial metal layer on the semiconductor substrate before step (a) of forming the sacrificial metal atomic layer.

3. The method of claim 2, wherein while the initial sacrificial metal layer is formed, the semiconductor substrate is heated to 300 ~ 500°C.

4. The method of claim 2, wherein the initial sacrificial metal layer is formed of the same material as the sacrificial metal atomic layer.

5. The method of claim 2, wherein the initial sacrificial metal layer is formed using the same reaction gas as the reaction gas used for forming the sacrificial metal atomic layer.

6. The method of claim 1, wherein while the sacrificial metal atomic layer and the metal atomic layer are formed, the semiconductor substrate is heated to 300 ~ 500°C.

7. The method of claim 1, wherein the Gibbs free energy of a composition including a metal atom of the sacrificial metal atomic layer and a halogen atom of the metal halide gas is higher than that of the metal halide.

8. The method of claim 7, wherein the sacrificial metal atomic layer is formed by reacting a sacrificial metal source gas and a reducing gas with each other.

9. The method of claim 8, wherein the reducing gas is one selected from the group consisting of H_2 gas and silane gas.

10. The method of claim 7, wherein the metal halide gas is one selected from the group consisting of $TiCl_4$ gas, a $TaCl_5$ gas, $HfCl_4$ gas, $ZrCl_4$ gas, TiI_4 gas, TaI_5 gas, HfI_4 gas, ZrI_4 gas, $TiBr_4$ gas, $TaBr_5$ gas, $HfBr_4$ gas, $ZrBr_4$ gas, TiF_4 gas, TaF_5 gas, HfF_4 gas and ZrF_4 gas.

11. The method of claim 10, wherein when the metal halide gas is $TiCl_4$ gas, the sacrificial metal layer is one selected from the group consisting of an Al layer, a La layer, a Pr layer, an In layer, a Ce layer, a Nd layer and a Be layer.

12. The method of claim 11, wherein the sacrificial metal source gases used for the Al layer, the La layer, the Pr layer, the In layer, the Ce layer, the Nd layer and the Be layer are precursors containing Al, La, Pr, In, Ce, Nd and Be, respectively.

13. The method of claim 12, wherein the precursor containing Al is one selected from the group consisting of $(C_4H_9)_2AlH$, $(C_4H_9)_3AlH$, $(C_2H_5)_3Al$, $(CH_3)_3Al$, $AlH_3N(CH_3)_3$, $(CH_3)_2AlH$, and $(CH_3)_2C_2H_5N{:}AlH_3$.

14. The method of claim 12, wherein the precursor containing La is one selected from the group consisting of $(C_5H_5)_3La$ and $(C_2H_7C_4H_4)_3La$.

15. The method of claim 12, wherein the precursor containing Pr is one selected from the group consisting of $(C_5H_5)_3Pr$ and $(C_3H_7C_5H_4)_3Pr$.

16. The method of claim 12, wherein the precursor containing In is one selected from the group consisting of C_2H_5In, $(CH_3)_5C_5In$, $(C_2H_5)_3In$ and $(CH_3)_3$ In.

17. The method of claim 12, wherein the precursor containing Ce is one selected from the group consisting of $(C_5H_5)_3Ce$ and $((C_5H_5)C_5H_4)_3Ce$.

18. The method of claim 12, wherein the precursor containing Nd is one selected from the group consisting of $(C_5H_5)_3Nd$ and $(C_3H_7C_5H_4)_3Nd$.

19. The method of claim 12, wherein the precursor containing Be is $Be(C_2H_5)_2$.

20. The method of claim 2, further comprising the step of purging the peripheral portion of the resultant structure where the initial sacrificial metal layer is formed, with an inert gas, before step (a) of forming the sacrificial metal atomic layer.

21. The method of claim 1. further comprising the step of purging the peripheral portion of the resultant structure where the sacrificial metal atomic layer is formed, with the inert gas, before step (b) of forming the metal atomic layer.

22. The method of claim 20. wherein the inert gas is one selected from the group consisting of N_2 gas and Ar gas.

23. The method of claim 21, wherein the inert gas is one selected from the group consisting of N_2 gas and Ar gas.

24. The method of claim 1. further comprising the step of forming an ohmic layer at the interface between the semiconductor substrate and the plurality of metal atomic layers, by reacting the plurality of metal atomic layers and the semiconductor substrate with each other using an annealing process after step (c) of stacking the plurality of metal atomic layers.

25. The method of claim 24, wherein during the annealing, an ambient gas is one selected from the group consisting of Ar gas. N_2 gas and NH_3 gas.

26. The method of claim 24. wherein the ohmic layer is a metal silicide layer.

27. A method for forming a metal silicide layer. comprising the steps of:
forming a sacrificial metal atomic layer on a semiconductor substrate; removing the sacrificial metal atomic layer and at the same time forming a metal atomic layer on the

semiconductor substrate by reacting the sacrificial metal atomic layer with a metal halide gas;

forming a silicon atomic layer on the metal atomic layer; and

alternately stacking a plurality of metal atomic layers and a plurality of silicon atomic layers on the semiconductor substrate by forming the sacrificial metal atomic layer, the metal atomic layer and the silicon atomic layer in sequence at least once.

28. The method of claim 27, further comprising the step of forming an initial sacrificial metal layer on the semiconductor substrate before the step of forming the sacrificial metal atomic layer.

29. The method of claim 28, wherein while the initial sacrificial metal layer is formed, the semiconductor substrate is heated to 300 ~ 500°C.

30. The method of claim 28, wherein the initial sacrificial metal layer is formed of the same material as that of the sacrificial metal atomic layer.

31. The method of claim 28, wherein the initial sacrificial metal layer is formed using the same reaction gas as the reaction gas used for forming the sacrificial metal atomic layer.

32. The method of claim 27, wherein while the sacrificial metal atomic layer, the metal atomic layer and the silicon atomic layer are formed, the semiconductor substrate is heated to 300 ~ 500°C.

33. The method of claim 27, wherein the Gibbs free energy of a composition consisting of a metal atom of the sacrificial metal atomic layer and a halogen atom of the metal halide gas is higher than that of the metal halide.

34. The method of claim 33, wherein the sacrificial metal atomic layer is formed by reacting a sacrificial metal source gas with a reducing gas.

35. The method of claim 34, wherein the reducing gas is one selected from the group consisting of H_2 gas and silane gas.

36. The method of claim 35, wherein the metal halide gas is one selected from the group consisting of $TiCl_4$ gas, $TaCl_5$ gas, $HfCl_4$ gas, $ZrCl_4$ gas, TiI_4 gas, TaI_5 gas, HfI_4 gas, ZrI_4 gas, $TiBr_4$ gas, $TaBr_5$ gas, $HfBr_4$ gas, $ZrBr_4$ gas, TiF_4 gas, TaF_5 gas, HfF_4 gas and ZrF_4 gas.

37. The method of claim 36, wherein when the metal halide gas is $TiCl_4$ gas, the sacrificial metal layer is one selected from the group consisting of an Al layer, a La layer, a Pr layer, an In layer, a Ce layer, a Nd layer and a Be layer.

38. The method of claim 37, wherein sacrificial metal source gases used to form the Al layer, the La layer, the Pr layer, the In layer, the Ce layer, the Nd layer and the Be layer are precursors containing Al, La, Pr, In, Ce, Nd and Be respectively.

39. The method of claim 38, wherein the precursor containing Al is one selected from the group consisting of $(C_4H_9)_2AlH$, $(C_4H_9)_3AlH$, $(C_2H_5)_3Al$, $(CH_3)_3Al$, $AlH_3N(CH_3)_3$, $(CH_3)_2AlH$ and $(CH_3)_2C_2H_5N{:}AlH_3$.

40. The method of claim 38, wherein the precursor containing La is one selected from the group consisting of $(C_5H_5)_3La$ and $(C_2H_7C_4H_4)_3La$.

41. The method of claim 38, wherein the precursor containing Pr is one selected from the group consisting of $(C_5H_5)_3Pr$ and $(C_3H_7C_5H_4)_3Pr$.

42. The method of claim 38, wherein the precursor containing In is one selected from the group consisting of C_2H_5In, $(CH_3)_5C_5In$, $(C_2H_5)_3In$ and $(CH_3)_3In$.

43. The method of claim 38, wherein the precursor containing Ce is one selected from the group consisting of $(C_5H_5)_3Ce$ and $((C_5H_5)C_5H_4)_3Ce$.

44. The method of claim 38, wherein the precursor containing Nd is one selected from the group consisting of $(C_5H_5)_3Nd$ and $(C_3H_7C_5H_4)_3Nd$.

45. The method of claim 38, wherein the precursor containing Be is $Be(C_2H_5)_2$.

46. The method of claim 28, further comprising the step of purging the peripheral portion of the resultant structure where the initial sacrificial metal layer is formed, with an inert gas, before the step of forming the sacrificial metal atomic layer.

47. The method of claim 27, further comprising the step of purging the peripheral portion of the resultant structure where the sacrificial metal atomic layer is formed, with an inert gas, before the step of forming the metal atomic layer.

48. The method of claim 27, further comprising the step of purging the peripheral portion of the resultant structure where the metal atomic layer is formed, with an inert gas, before the step of forming the silicon atomic layer.

49. The method of claim 46, wherein the inert gas is one selected from the group consisting of N_2 gas and Ar gas.

50. The method of claim 47, wherein the inert gas is one selected from the group consisting of N_2 gas and Ar gas.

51. The method of claim 48, wherein the inert gas is one selected from the group consisting of N_2 gas and Ar gas.

52. The method of claim 27, wherein the silicon atomic layer is formed by reacting with a silicon source gas.

53. The method of claim 52, wherein the silicon source gas is one selected from the group consisting of SiH_4 gas, Si_2H_6 gas, $(CH_3)_3SiC{\equiv}CSi(CH)_3$ gas, $((CH_3)_3Si)_2CH_2$ gas, $(CH_3)_3CSi(CH_3)_2Cl$ gas, $(C_4H_9)SiCl_3$ gas, $(CH_3)_3SiN(C_2H_5)_2$ gas, $(CH_3)_2SiCl_2$ gas, $((CH_3)_2Si\text{-})_n$ gas, $(C_6H_5)_2SiCl_2$ gas, $(C_6H_5)_2SiH_2$ gas, $C_2H_5SiCl_3$ gas, $Cl_3SiSiCl_3$ gas, $(CH_3)_3SiSi(CH_3)_3$ gas, CH_3SiCl_2H gas, $(CH_3)(C_6H_5)SiCl_2$ gas, $C_6H_5SiCl_3$ gas, $SiBr_4$ gas,

$SiCl_4$ gas. SiF_4 gas. SiI_4 gas. $(C_{32}H_{16}N_8)SiCl_2$ gas, $Si(Si(CH_3)_3)_4$ gas, $Si(CH_3)_4$ gas, CH_3SiCl_3 gas, $HsiCl_3$ gas, $(C_2H_5)_3SiCl$ gas. $CF_3Si(CH_3)_3$ gas. $(CH_3)_3SiCl$ gas. $(CH_3)_3SiH$ gas, $(CH_3)_3SiC{\equiv}CH$ gas, $(C_5H_5)Si(CH_3)_3$ gas, $(C_5(CH_3)_5)Si(CH_3)_3$ gas. $(C_6H_5)_3SiCl$ gas, $(C_6H_5)_3SiH$ gas. $((CH_3)_2N)_3CH$ gas and $CH_2{=}CHSiCl_3$ gas.

54. The method of claim 27, further comprising the step of annealing at a predetermined temperature, after alternately stacking the metal atomic layer and the silicon atomic layer on the semiconductor substrate.

55. The method of claim 54. wherein the annealing is performed through one selected from the group consisting of a rapid thermal process. a furnace annealing process and vacuum thermal treatment.

56. A method for forming a metal silicide layer. comprising the steps of:

forming a silicon atomic layer on a semiconductor substrate;

forming a sacrificial metal atomic layer on the silicon atomic layer;

removing the sacrificial metal atomic layer and concurrently forming a metal atomic layer on the semiconductor substrate by reacting the sacrificial metal atomic layer with a metal halide gas; and

alternately stacking a plurality of silicon atomic layers and a plurality of metal atomic layers on the semiconductor substrate by forming the silicon atomic layer. the sacrificial metal atomic layer and the metal atomic layer in sequence at least once.

57. A method for forming a metal silicide layer substantially as shown in and/or described with reference to any of Figures 1, 2 and 5 to 7 of the accompanying drawings.

58. A method for forming a metal silicide layer substantially as shown in and/or described with reference to any of Figures 3 to 7 of the accompanying drawings.

The Patent Office

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UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

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Int Cl (Ed.6): H01L

Other: ON LINE,W.P.I.

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	US5405806 MOTOROLA	

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